AN ANALYSIS OF CERTAIN REMOTE SENSING TECHNIQUES FOR COUNTING LARGE NUMBERS OF GEESE

An abstract of a Thesis by
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The problem. The objective of the study was to develop a technique of estimating large numbers of geese accurately and to provide a permanent reproducible record of the estimate. The technique to be developed was to utilize equipment easily available to field personnel.

Procedure. The red, blue, green, and infra-red electromagnetic wave lengths were examined for use in the technique. The band providing the maximum contrast between the geese and the natural background was analyzed to determine the accuracy and reproducibility of estimated goose numbers.

Findings. The blue color band should be used when aerial photography is used to count geese. Count estimates obtained with the Digacol Model 4010 density analyzer (Iowa Geological Survey Remote Sensing Lab.) did not have the accuracy desired. When the photo negatives were changed to positives and enlarged, the accuracy improved to acceptable limits.

Conclusions. The techniques developed included: using a blue pass filter (Kodak 47 B), verticle aerial photography, photographing resting on a uniform background (preferably water) at an altitude where the geese are not disturbed but can be photographed easily, and finding that easily available equipment can be used to estimate large numbers of geese. Finding the limitations of the density analyzing equipment available lead to the acknowledgement that machinery does exist that can use the photographs to count geese.

Recommendations. A method for photographing geese has been developed however estimating goose numbers by density analyzing is dependent upon the availability and sophistication of the equipment. For reproducible accurate count estimates, photographs and negatives should be submitted to the EROS Data Center, Sioux Falls, South Dakota.

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A Thesis

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The School of Graduate Studies

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Master of Arts

by

John Dean Beamer

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INTRODUCTION

Since the advent of modern wildlife management the persistent problem of censusing wildlife populations has remained an enigma. The complete success of most wildlife management techniques are predicated upon the solution of the impediment. If the magnitude of the population to be managed is unknown, the amplitude of the success of a certain technique cannot accurately be defined. To circumvent part of this problem, methods such as trend indices (Eberhardt, 1969) and statistical treatments (Overton and Davis, 1969) of the data have been employed. In many situations, these methods are adequate. These solutions however, lack the precision that many professionals desire. In most cases, the data, which is the basis for the estimations, cannot be examined for accuracy. Frequently, the data is collected by several people and requires a subjective evaluation from each participant. In addition, behavioral patterns of the wildlife, environmental features, and time relationships of the data gathered all influence the final population estimates (Eberhardt, 1969).

In waterfowl management, numbers have always played an integral part in management manipulations. For example, hunting seasons, bag limits, and flyway regulations are all affected by the numbers game. In all waterfowl population estimations, a check for accuracy is difficult. Contributing to this inadequacy are the extreme mobility of the waterfowl and the large number that at times must be counted. In addition, it is necessary to count the waterfowl over a large area within a relatively short time interval.

One solution seemed to lie in the combination of photography with an aerial platform. An aircraft would shorten the time frame and increase the mobility of the observer. The photograph would add a permanence to the count that had been lacking. With this technology it would seem that the problem should be solved. Mobility did result from using the aircraft but, the large number of waterfowl still presented a problem for photography. In addition blue geese, Canada geese, and white-fronted geese all have a coloration that blends well with their natural background of shallow water, mud-flats, and stubble.

Large numbers present a rather unique problem. In one instance a relatively small number of greater snow geese (24,263) (Overton and Davis, 1969) were counted from a photograph. This count was accomplished by pricking each goose image with a pin (to insure not counting the same bird more than once). This example demonstrates the tediousness required to obtain accuracy. Also, this photograph was of only one highly visible specie of waterfowl. In addition, actual counts are made of several flocks that would vary in size in some cases several times larger than the example. Some counts are made on a weekly bases. The data that accumulated from these counts would in many cases overwhelm an effort to count each individual goose. Also, the problem of the background still exists.

In counting geese in the field, one basic procedure used is as follows: The observer approaches the geese in an aircraft from an altitude of several thousand feet. The altitude is decreased until individual geese can be seen without frightening the entire flock. From this altitude the aircraft circles the flock while the observer estimates the number of birds. This is sometimes done by counting 25-50 birds. This known number is then used to estimate a block size of first 100, then 500, and finally 1000 if the flock is large enough to warrant it. These blocks (100, 500, or 1000) are then used to estimate the number of birds being observed. Light conditions, physical discomfort of the observer, varying densities of the flock, changing flock configurations, and variable backgrounds all influence this type of estimation. Generally, the estimation is made several times and in some cases by two observers in the same aircraft. However, a reliable check for accuracy is not possible. In most cases the accuracy probably varies from one area to the next but again there is no way to check this using the above method of estimation.

From the above illustrations, two basic problems emerge. First there is a lack of contrast between the environmental background and certain species, e.g., blue geese, *Chen* caerulescens and Canada geese, Branta canadensis. The second problem involves counting large numbers of geese rapidly with an acceptable degree of accuracy.

Until recently, technology had not advanced to the stage that solutions to these problems could be expected. Increased interest in remote sensing by many people over the last five years has indicated that techniques may exist that could be applied to solving wildlife censusing problems (American Society of Photogrammetry, 1968; Avery, 1970). With that in mind, an investigation of some of these new techniques was initiated.

Because much of the work in remote sensing involved plants, near infra-red photography has received the most attention (Smith, 1968). This interest has created a large body of knowledge regarding infra-red photography. Because of this large amount of information, the infra-red band seemed a logical place to start. At the same time the primary color bands (red, blue, and green) had not been as popular. Therefore these bands were also included in the study.

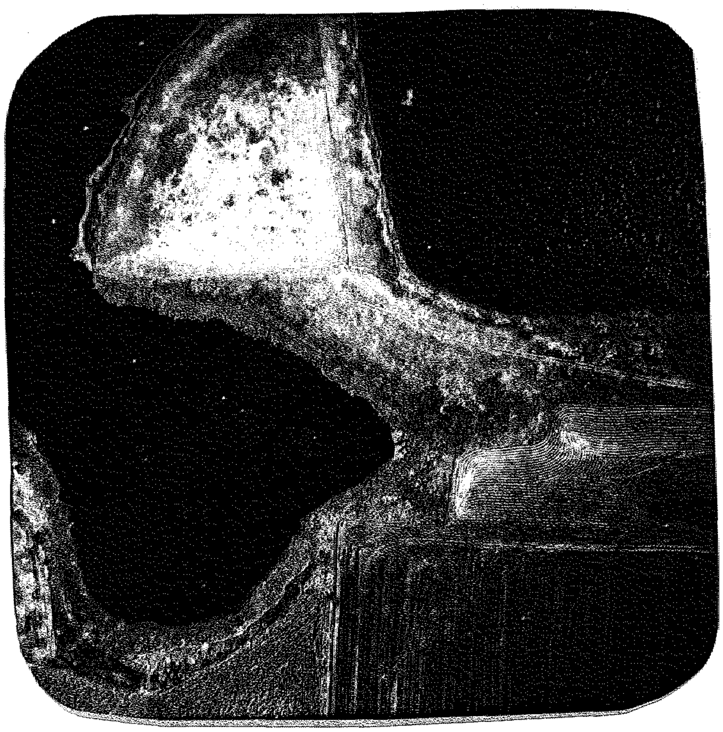
The project was designed to take advantage of the existing information and investigate three major areas. First in priority was to determine the optimum color band or combination of color bands to be used to photograph geese. The second objective was to examine the capability of available machinery to accurately estimate waterfowl numbers. The third item was to use and examine available equipment to determine if the techniques could be easily used by a wide range of field personnel.

METHODS AND MATERIALS

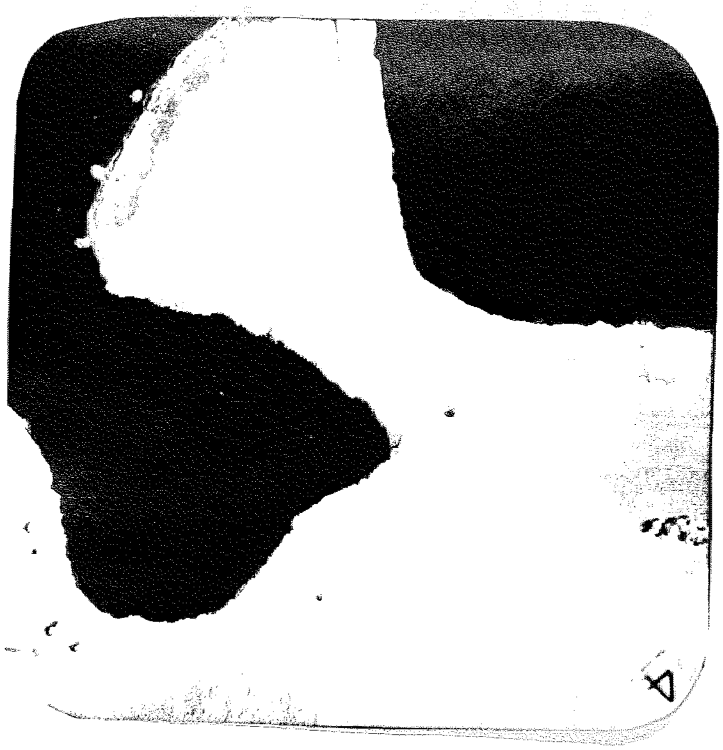
The initial phase of the project was to determine the correct wavelength and altitude to examine the waterfowl. To accomplish this, photographs were taken at 3,000 and 6,000 feet altitude with a multispectral camera (I^2S Model Mark I, focal length 150 mm.). The camera was mounted in the bottom of a Piper Cherokee 260 outfitted for vertical aerial photography. The film used was Kodak 2424 Type EK aerial graphic black and white infra-red. Single band pass filters of red, blue, green, and infra-red were used on the camera. By putting the developed film transparency (Figures 1 and 2) on a color additive viewer (International Imagery Systems, model 6040) comparisons of various combinations and single color bands (red, blue, green, black and white, and both false color and black and white infra-red) could be made.

The target used for the initial phase was a pen of captive Canada geese, _Branta canadensis_. These birds were chosen because of their relatively small contrast with their natural background. The geese were the property of the Iowa State Conservation Commission and located on the Ingham-High Management Unit, Emmet County, Iowa.

The next phase of the project concerned data acquisition

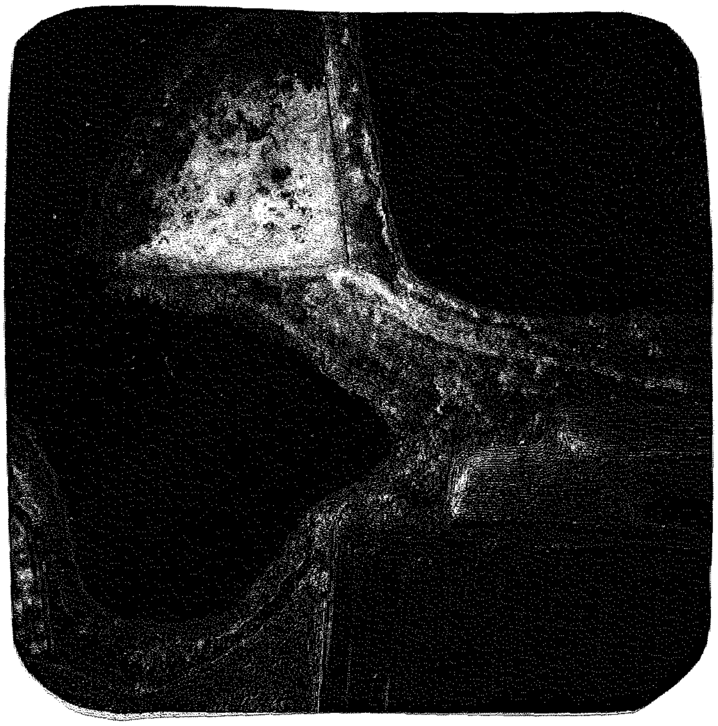


Blue

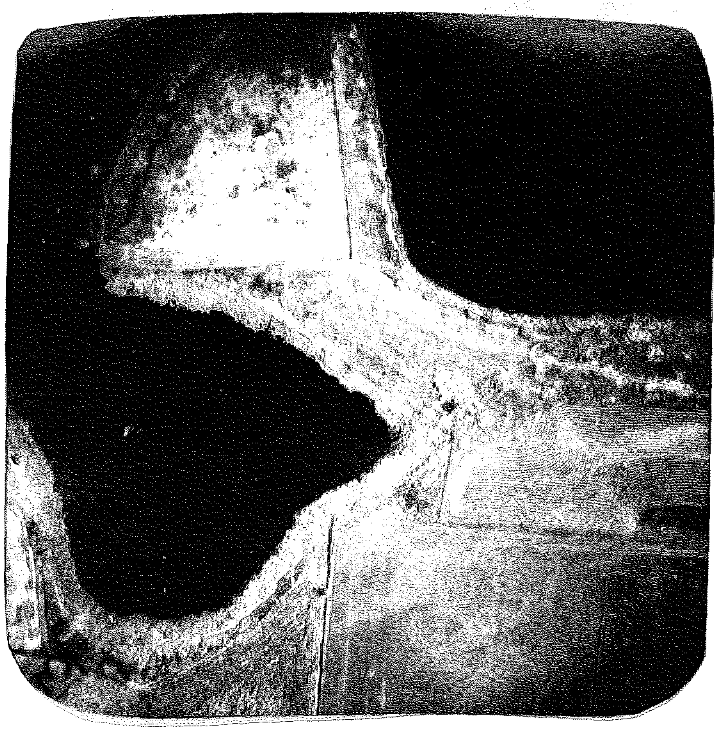


IR

Figure 1. Prints of Multispectral Transparency of Blue and I-R bands.



Red



Green

Figure 2. Prints of Multispectral Transparency of Red and Green Bands.

for use in analyzing the censusing method. Ease of equipment acquisition and economy were considered important and the gear was chosen with this in mind. If the technique is to have applicability, field personnel must be able to use it. The aircraft used in this project was the Cessna 150. This aircraft met the above requirements and had the necessary wing-over the fuselage design for taking the vertical photographs with a hand held camera. The perpendicular field is necessary to prevent the body of one resting goose from partially obscuring that of another goose in the photograph.

To take the photographs a Mamiya Universal Press Model with a 100 mm lens was chosen. The film selected was Kodak Tri X 120 black and white film. The fine grain size of the film and the larger format (2 1/4" by 2 3/4") were the reasons for its selection.

The filter used was a Kodak 47 B gelatin filter. This is a blue band pass filter with a dominant wavelength design of 449.4 nanometers. For extensive field use a glass filter would prove more durable than the gelatin type.

The target selected for the second phase was a flock of blue geese _Chen caerulescens_ and snow geese _Chen hyperborea_ resting on Forney Lake, Fremont County, Iowa. The birds were in spring migration and the photos were taken on a clear afternoon in late March 1971. Blue and snow geese were selected for the final target because of the contrast diversity their coloration provides with the background (Figure 3). The photographs were taken from the aircraft at 1000 feet above the ground. To obtain the photograph at a near vertical plane it was necessary for the photographer to lean out the window while the aircraft was in approximately a 60° bank directly over the geese. Care was taken not to include either the wing strut or landing gear in the photo. Photographs were taken of geese resting on several different backgrounds. The backgrounds included mud-flats, old corn fields, grass stubble, and water.

The film was processed in the normal commercial manner. After the film had been developed and the negatives examined, the negatives that provided the greatest contrast were selected for counting (Figure 4). To isolate the areas of the negatives to be counted, a mask of black paper was taped over the portion of the negative not being used (Figure 5). The mask contained a cutout window of known dimensions. This window was placed over the geese to be counted. The dimensions of the window were used to compute the ground area covered by this section of the photograph. The formula used was: (Eastman Kodak Co., 1971).

$$\text{Scale} = \frac{\text{lens focal length}}{\text{altitude of aircraft}}$$

Thus at 1,000 feet altitude the scale would be 1" = 254 feet.

Information supplied by the Iowa Conservation Commission Waterfowl Biologist (Richard Bishop) indicated that an average goose would measure 8" wide and 20" long. Using the

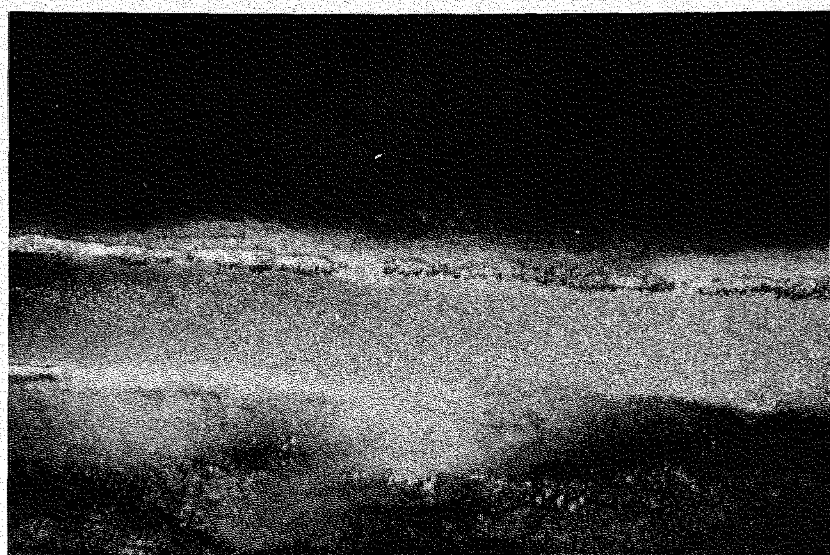


Figure 3. Vertical photograph of Geese at Forney Lake, March 1971, Altitude 1000'.

Figure 4. Processed Negative of Geese. Taken at Forney Lake, Iowa, March, 1971, Altitude 1000 feet.

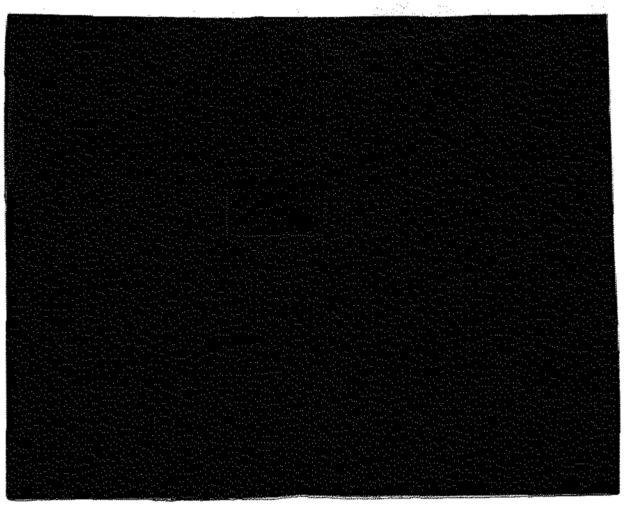


Figure 5. Illustration of Masked Negative Used to Isolate Area to be Analyzed.

formula for finding the area of an elipse ($A = \pi ab$) where $\pi = 3.14$ and a and b are the semi axes of the elipse, the area calculated was 0.87 ft.^{2} per goose (Hodgman, 1954).

After the negative had been prepared, the final step could be started. The masked negative was placed on the light table of the Digacol Model 4010 density analyzer system. The window was scanned with the system's video camera. The image was transmitted to the analyzer screen. The computer connected to the analyzer was programmed to calculate the percentage of screen occupied by the transmitted image. To begin with, the percentage of the screen occupied by the entire window was calculated by the computer. The area of the screen image was then calculated by dividing the known ground area of the window by the percentage of the screen occupied by the window. Next, the percentage of the screen occupied by the geese was determined by using the density slicer to separate the geese from the rest of the photo. This percentage figure was then multiplied times the calculated screen area to determine the number of square feet occupied by geese in the photograph window. This figure was divided by 0.87 (average area in square feet occupied by one goose) to determine the actual number of geese estimated occurring in the window of the photograph negative. To determine the accuracy of the estimate, the geese in the negative window were counted by the observer. This was accomplished by placing the negative window over a small light table and counting with the aid of a 8x magnification lens (Agfa Lupe 8x 35 mm slide viewer). The two numbers were subtracted to determine the degree of error (see Table 1).

RESULTS

In the initial phase of the project, primary interest was directed toward finding the best wavelength for photographing the geese. By using the multispectral camera, an examination of several options was available using the photographs obtained on only one flight. The inspection of each band and combinations of bands by the observer and two members of the Remote Sensing Staff at the University of Iowa resulted in the blue band being selected as providing maximum contrast between geese and background. Many filters are available to separate the blue band but after consulting Kodak's Filter Guide (Eastman Kodak Co., 1970), the Kodak 47B filter was chosen. Light transmitted and color separation were the most important details considered in this choice. This filter transmits most light at about 449.4 nanometers. This is somewhat short of the pure blue wavelength of 475 nanometers. The window is shut for most light at 500 nanometers and above (0.17% transmittance at 500 nanometers). The other end of the light window was closed at approximately 400 nanometers (0.16% transmittance below 400 nanometers). No other filter available could offer this combination of relatively high light transmittance combined

Table 1. Comparison of geese (estimated and counted) Forney Lake, Iowa, March 1971, from three selected photographs

	Photograph Number		
	1	2	3
Window Size (inches)	0.32 x 0.35	0.37 x 0.33	0.29 x 0.35
Ground Area (feet)	81.3 x 88.9	93.9 x 88.8	73.6 x 88.9
Ground area (feet^2)	7227.5	7868.8	6543.0
% screen area	61.4	59.6	65.3
% geese area	4.25	4.0	5.5
Screen Area (feet^2)	11,771.2	13,202.7	10,019.9
Geese Area (feet^2)	500	528	551
Estimated Geese	575	607	633
Actual Geese	425	338	194
Error	150	269	439
% Error	33.3	79.6	226.3
Standard Deviation of % error.....80%			

with a narrow light window (see Figure 6).

In selecting the blue band all combinations were evaluated. If only water was involved, the near infra-red band could also be used. Some contrast was lost on this band when the target was over mud-flats. The near infra-red band also posed another problem. If black and white infra-red film was to be used, an infra-red pass filter had to be used in conjunction with the film. Most cameras used are of the single lens reflex type and the target cannot be seen through the lens viewing system because of the filter. Color transparencies lack the permanency that black and white film has so color infra-red was not considered.

As mentioned before, the altitude used hinges upon the behavior of the geese. For this particular project, 1000 feet above the ground worked well. The criteria was to get as close as possible to the geese and still be able to get the entire flock in the camera focal plane.

The initial target of Canada geese, Branta canadensis, was chosen because of their slight contrast with their natural background of mud-flats, water, and browse plants. Their color is also near the coloration of both blue geese, Chen caerulesens, and white-fronted geese, Anser albifrons. By selecting a bird with small contrast with its background, the capability of the technique could be more thoroughly examined. Comparison of white-fronted geese could not be made but

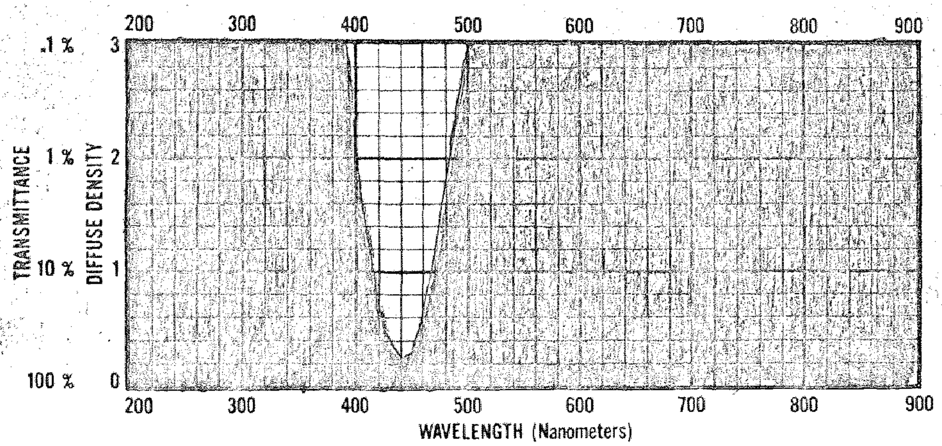


Figure 6. Graph Illustrating wavelength Passed by Filter 47B.

Canada and blue goose comparisons seemed to justify this reasoning. In comparison of blue geese and snow geese the contrast is obvious. In comparison of blue geese with Canada geese, size relationships seemed to be of little significance. If there was a difference in the way the birds could be seen, it was too small to measure.

A near vertical photograph is essential for this technique. The vertical photograph insures that no goose will obscure part or all of another goose. Another requisite is that the birds be at rest. Again this is important because in flight a risk of not seeing each bird entirely is taken. Movement on the water was of little consequence. Shutter speed was such that swimming of the geese could easily be stopped. A 60° bank of the aircraft allowed the photographer to easily take good photos without having to lean out the window too far. The photographs must be taken through an open window to eliminate distortion and reflection from the aircraft window. Time should be taken to explain the technique to the pilot prior to take-off. It is important that a constant altitude of a known value be maintained throughout each photo taking sequence. Care must be taken not to include either the landing gear or the wing structure in the photographs. Experience will help in checking the field of view prior to exposing the film.

Both the camera and film selected worked adequately. The film was processed through normal commercial channels to simulate field conditions. No special instructions were given. The prints were used to evaluate the negatives having the best contrast. The prints are not necessary, but did aid in the initial selection of negatives to be used. A fine grain film was judged to give the best results; however, no other film of a different ASA value than the Tri X was used.

The second target was a flock of blue and snow geese. It was felt that if the machinery was unable to separate the lower contrast birds (blue geese) the capability could be tested on higher contrast birds (snow geese). As mentioned above it is necessary to insure that all of each individual target goose is photographed. The geese normally rest at mid-day and photography was timed to take place during this time frame. The photo was taken on a clear day but it was the feeling of the observer that light to moderate overcast would not hinder the operation as long as enough light was available to properly expose the film and the cloud ceiling was high enough for flying the correct altitude above the geese. It is also important not to include sunstreaks in the photograph if the mission is undertaken on a clear day.

Several different kinds of backgrounds were photographed with geese on them. The result was that a very uniform background was found to be necessary if the machinery used (Digical density analyzer) is to perform at its maximum. Differences in ground moisture content, vegetation height, and topographical features precluded all backgrounds tested but water. Wind and sun streaks also made variable densities some of which matched the density of light reflected by a target goose.

To eliminate this interference the mask of black paper was developed. By moving the mask until only birds on a uniform background could be seen, the machine capabilities could be tested. The dimensions of the window in the mask were important. These dimensions were used to calculate the area of ground covered by the mask window over the photograph. This in turn was used to calibrate the analyzer for the experiment.

Several problems occurred with the machinery. As mentioned above, the machinery was not selective enough to separate the geese from the background at the level of proficiency desired. The window was developed to reduce the affects of the background variability. The result was a halo of light reflectance around the frame of the window that could not be removed. This halo was felt to contribute to the inaccuracy demonstrated in Table 1.

To pursue this idea further, additional photographic techniques were employed. The window and its negative were used to expose a large sheet of film (10" x 12" Super XX Pan Kodak 4142 Estar-Thick Base) and therefore enlarge the window several times. This process developed a film positive that was examined by the machine (Figure 7). The results of this

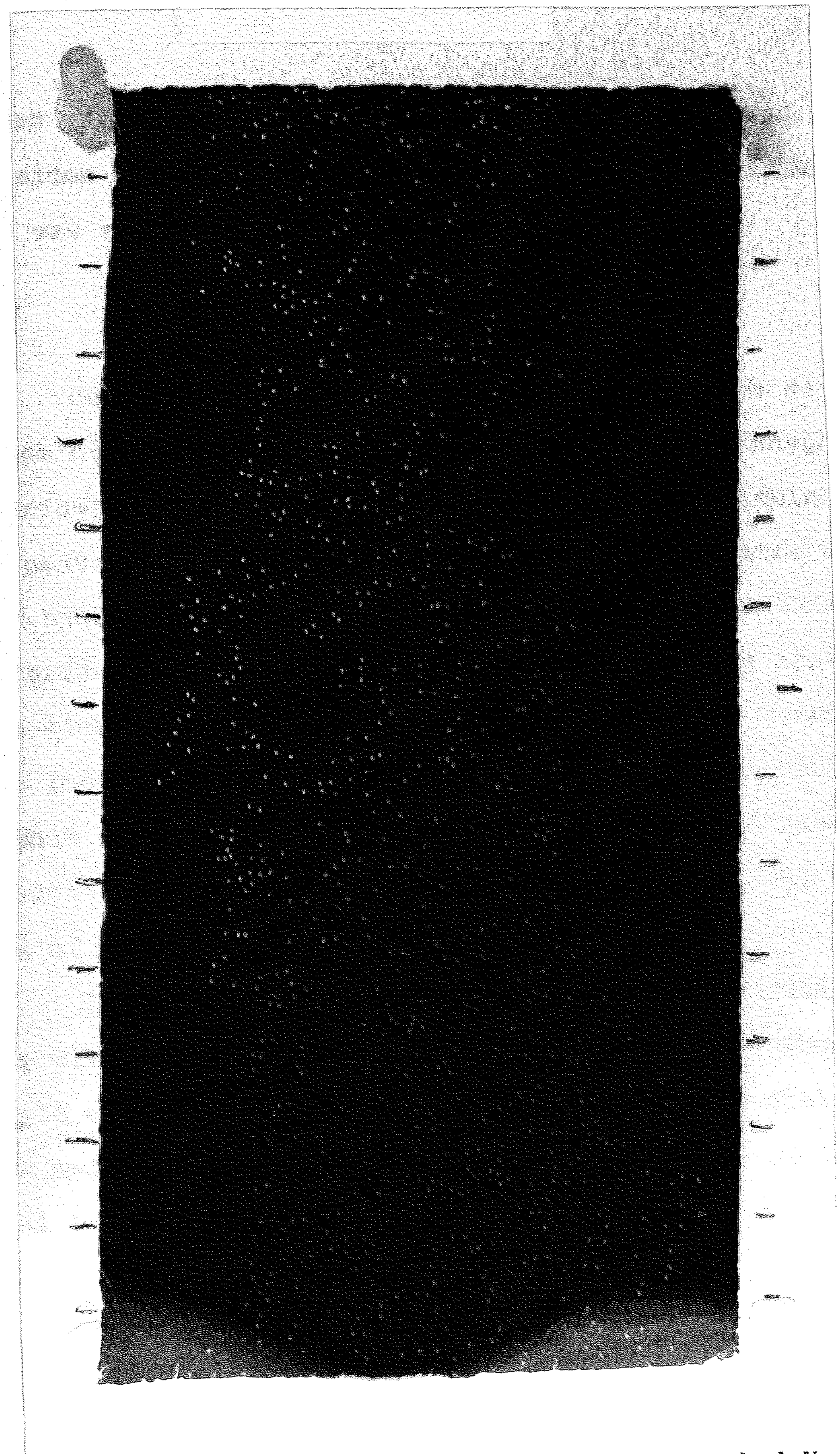


Figure 7. Enlarged Film Positive of Marked Negative Window.

effort are included in Table 2. This method allowed most of the video screen to be used and also the effect of the light halo was reduced.

DISCUSSION

Using the blue color band to photograph the waterfowl in the study provides a valuable tool for the censusing of waterfowl. It also points out some parameters within which the photography must be used. Because of the nature of the blue band, certain atmospheric conditions will inhibit the performance of this band. Haze has the effect of scattering blue light. This effect forces the users of the technique to take into account weather conditions. All of the work done in this study was done on a bright clear day. No research was done on haze maximums that could be tolerated by this type of photography.

The altitude of the photography is not critical if held within the criteria mentioned in this text. Focal length of the camera lens will affect the camera field of view and in turn the altitude will be a function of the focal length. On any given film format the longer the lens focal length the smaller the area photographed if the distance is constant.

It is important that the geese are resting on water during the photography. If the birds are in flight, the constant (0.87 ft^2) would not be valid. The area size of the

Table 2. Comparison of geese (estimated and counted) Forney Lake, Iowa, March 1971, from four selected film positives

	Enlargement Number			
	1	2	3	4
Window size (inches)	0.25 x 0.5	0.3125 x 0.5	0.3125^2	0.25 x 0.5
Ground dimensions (ft.)	63.5 x 127	79 x 127	79 x 79	63.5 x 127
Ground area (ft^2)	8,064.5	10,033	6,241	8,064.5
% Screen area	17.8	23.0	13.1	14.9
% Geese area	1.6	1.2	0.8	1.7
Screen area (ft^2)	45,303	43,621	47,641	54,120
Geese area (ft^2)	725	811	381	487
Estimated geese	833	702	438	560
Actual geese	951	902	549	688
Error	118	200	111	129
% Error	12.4	22.2	20.2	18.8
Standard deviation........4.2%				

goose would appear to vary to the camera because of wing movement of the birds in flight. Also in normal behavior over the loafing area, geese do not fly in formation. Because of this behavior, birds in flight would be at different altitudes and therefore geese at higher altitudes would mask some of the geese at lower altitudes in some cases.

A telephoto lens would be awkward because of the focal length phenomena. Also, movement and vibration would be magnified, which might affect image sharpness. A telephoto lens also requires more light than a shorter focal length lens to expose the film to the same level. On a marginal day the mission might not be able to be completed because of this characteristic.

The camera used should have as large a film format as is easily available. The less need for magnification the better. No attempt was made to analyze any particular camera for performance. A 35 mm camera might work but no attempt was made with this size film format. The film processing was adequate. This demonstrates that field use in this respect was feasible. The film used was of a type available at most drug stores. No special film was used because of the field use feasibility requirement of the study. Experiments with extreme contrast films was another area left unexplored.

The experiment with the density analyzing equipment left much to be desired. It was evident that without special processing, the film imagery could not be utilized by the machinery with any degree of accuracy (Table 1).

At the completion of this study, a new density analyzer is being installed at the EROS Data Center in Sioux Falls, South Dakota. The much advanced capabilities of this machine may lend it to the application of the photograph technique described above. If this is the case photos could be taken by field personnel and sent to the Center for analysation. Turn around time can not now be predicted but increased accuracy should result from using a more sophisticated density analyzer.

The purpose of this study was to determine a method by which geese can be photographed and numbers determined. By identifying the blue band as the best wave length for photographing and in determining the accuracy of the method, field personnel now have available to them a means by which records can be obtained to assess the accuracy of their estimations. Photographic procedures developed illustrate the importance of vertical photographs, resting geese, uniform background and the effects of altitude and weather.

SUMMARY

1. Multispectral photography was used to examine four color bands (blue, red, green, and infra-red) for best photographic capabilities.

2. It was found that the blue band was much better than the other three color bands examined for contrasting geese with the natural background.

3. Photographs were taken with a blue pass filter (Kodak 47B) on a hand held camera (Mamiya press model) to obtain imagery for analysis of the capabilities of the Digacol Density analyzer.

4. The area of geese on the negative was blocked off with a black paper mask. This area was then processed by the machine to estimate the number of geese in the area of interest.

5. Because of the effect of a light halo around the window of the mask, counts made in this manner were found to be inaccurate.

6. By using certain photographic processes imagery was produced that could be processed by the machine without the previous light halo effecting the counting of the geese.

7. Removal of the halo increased the accuracy to a level that would be acceptable. This result demonstrates that with a high level of machinery available, acceptable accuracy can be obtained.

8. A method for photographing geese to be counted was developed as follows:

a. Use a blue pass filter (Kodak 47B) on a camera with a lens of known focal length. The lens should not be of the telephoto variety.

b. Use Tri X film on as large a format as is available.

c. Photograph the geese while resting on a uniform background, e.g., water.

d. Use a light plane (150 Cessna) with a wing-over the fuselage design for economy and ease of taking vertical photography.

e. Record altitude the photographs are taken at to use for computing ground area covered by the photograph.

f. Record date and location of photography for future record needs.

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